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BOMEX Rainy Day Analysis

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BOMEX RAINY DAY ANALYSIS

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Abstract. An investigation was made during the Barbados Oceanographic and Meteorological Experiment (BOMEX) in 1969 to evaluate the possibility of determining total precipitation from the change in salinity or temperature at the ocean surface. Salinity-temperature-depth (STD) soundings were taken at 3-hr intervals during periods of no rain, and at 5- to 6-min intervals during periods of rain. Analysis of salinity data shows that during periods of no rain, salinity regularly fluctuated by $\pm$ 0.15°/oo. Fluctuations of this magnitude are likely to obscure possible salinity depressions due to rainfall. No rainfall-related long-term salinity depressions were evident. Many sharp, short-term depressions of salinity, on the order of 10 to 45 min, however, were observed during periods of rainfall.

Data were collected during the Barbados Oceanographic and Meteorological Experiment (BOMEX) in the summer of 1969, to evaluate the possibility of determining total precipitation from the change in salinity and temperature caused by that precipitation. For such an evaluation, "rainy day" salinity-temperature-depth (STD) soundings were taken during periods of rainfall, which provided STD data for one depth profile every 5 to 6 min. Two such periods, May 5 and May 26, 1969, were chosen for the study presented here, because on both days there is evidence of significant rainfall, and numerous STD data were obtained. Also, the rainy day data are preceded and followed by data for long periods without rain. The STD observations were made from the NOAA ship *Oceanographer* with a model 9006 STD system built by the Bissett Berman Corporation (now Plessey Environmental Systems). The ship was stationed at 17°30'N and 54°30'W, at the northeast corner of the BOMEX square array.

The exact influence of rainfall on the ocean surface is not well understood, although the following parameters may be involved. The magnitude of salinity change is expected to be dependent on the intensity and duration of the rainfall, turbulent mixing, and horizontal advection. Turbulent mixing is affected by wind speed, sea state, surface currents, and the stability of the density structure near the surface. Evidence of the formation of a stable density structure, coincident with rainfall, was observed by Ostapoff et al. (1972) on board the R.V. *Professor Zubov*, located at 5°N, 21°W (see fig. 1). In their experiment, STD soundings were made at 2-hr intervals during and following precipitation at sea. Periods of precipitation are indicated by the shower symbols in figure 1. The rainfall area was widespread and the rain rate was steady. Shipboard rain-gage measurements totaled 17.5 mm, and wind speed averaged about 4 m/sec. The salinity and temperature profiles in figure 1 show a stratified layer of less dense water forming within 4 hr after the beginning of the rainfall. Judging by the timing, this less dense layer was apparently caused by the precipitation. The stratified layer persisted above 10 m for about 12 hours, and was still clearly evident after 34 hr.

It was anticipated that the analysis of the BOMEX STD data might be characterized by similar salinity profiles, but this apparent surface accumulation and downward propagation of a low density layer was not observed in any of the BOMEX casts studied. Analysis of 3-hourly STD soundings on the *Oceanographer* for May 24 through May 27, presented in figure 2, shows a well-developed mixed layer over which salinity is essentially uniform with depth. In contrast with figure 1, the BOMEX mixed layer salinities were in a continuous state of flux, instead of being constant prior to rainfall. To show this variability in figure 2, a salinity profile at 2100 GMT, May 24, was chosen as a reference.

The salinity profiles in figure 2 are drawn on a similar scale as those in figure 1, yet no low surface salinity accumulation, specifically related to the preceding 30-mm rainfall, is observed. This indicates that the fresh water from a local rainstorm was advected away from the sampling area or that strong winds were mixing the rainwater uniformly throughout the mixed layer. In the latter case, a uniform decrease in salinity throughout the mixed layer would be observed.

The depth-averaged salinities for each sounding during the 3 days of observation were computed for increasing depths of 10 decibars, as shown in figure 3. The 0- to 10-decibar layer, which is least affected by the fluctuating base of the mixed layer, is seen to vary by about $0.15^{o}/oo$ during periods of no rain. These variations appear to be the product of a normally nonuniform ocean. Similar salinity fluctuations during periods of no rain are observed in the *Oceanographer* data for May 3 through May 6. Hypothetically, if the 30 mm of rain that fell on May 26 were contained essentially within the 0- to 10-decibar layer, and horizontal advection were negligible, the average salinity of this layer would have been changed by only $0.10^{o}/oo$. This change is not very different from the amplitude of the natural variability of salinity, and consequently could have been camouflaged.

We may so far conclude that in the BOMEX area, without knowledge of advection and mixing, a rainfall-caused salinity change of the same magnitude and time scale as a nonrainy salinity change, makes detection unlikely. When, however, the rainfall data are analyzed on a much shorter time scale, a phenomenon of salinity depression and recovery is observed.

During and following periods of rainfall, "rainy day" STD soundings were made at intervals of 5 to 6 min. By comparison of salinity profiles in terms of light showers vs. moderate rainfall (as reported by shipboard observers), the dynamic quality of salinity vs. depth, possibly as a consequence of the rainfall, becomes apparent. As figure 4 shows, a less dense, stably stratified layer is not seen to form in response to precipitation. A rapidly fluctuating salinity profile is, however, observed at times of heavier rain rates.

As shown in figure 5, when the salinity is averaged over 0 to 10 decibars for each 5- or 6-min sounding and integrated with previously plotted (fig. 3) 0- to 10-decibar average salinities, the slowly fluctuating trend of salinity observed during nonrainy periods is maintained. Noticeable on this slow salinity fluctuation are sharp depressions of salinity followed by rapid recoveries. STD soundings were not taken at a high sampling rate during nonrainy periods; therefore it is not possible to definitely correlate these short-term depressions with the rainfall rate. The salinity depressions are, however, of a magnitude that could have been caused by dilution due to precipitation. The rainfall that would be required to dilute seawater to a depth of 10 decibars by the amounts observed in figure 5 at 1120, 1300, 1640, and 1750 GMT is 20 mm, 37 mm, 20 mm, and 26 mm, respectively. These salinity depressions are the result of (1) dilution by precipitation and/or (2) advection of less saline water into the sampling area.

In conclusion, in the tropical region of BOMEX during the early part of the field project (May 1969), no long-term depressions of salinity were observed to occur in response to precipitation. The salinity fluctuations during periods of no rain were of the same magnitude as changes expected to be caused by dilution due to rainfall. The nonrainy variations in salinity therefore were likely to obscure rainfall-induced salinity depressions. Large changes in salinity were observed to occur and dissipate over short time periods, indicating that advection is an active mechanism in these salinity changes. The data reported by Ostapoff et al. (1973), which were apparently obtained under conditions of steadier, more widespread rain, show a longer term response of the salinity profile.

The analysis described here represents a mere suggestion of the effect of rainfall on the ocean surface. Without information on horizontal advection, rainfall spatial distribution, and rain rate, it is at best qualitative and leaves room for further investigation. Whether accumulated precipitation can be estimated from changes in salinity at the ocean surface remains inconclusive. This method cannot, however, be applied without knowledge of mixing and advective processes. The need for further study of the influence of precipitation on the surface layers of the ocean is indicated, not only as a secondary rain gage, but as a tracer in learning more about the microscale dynamics of the ocean surface.

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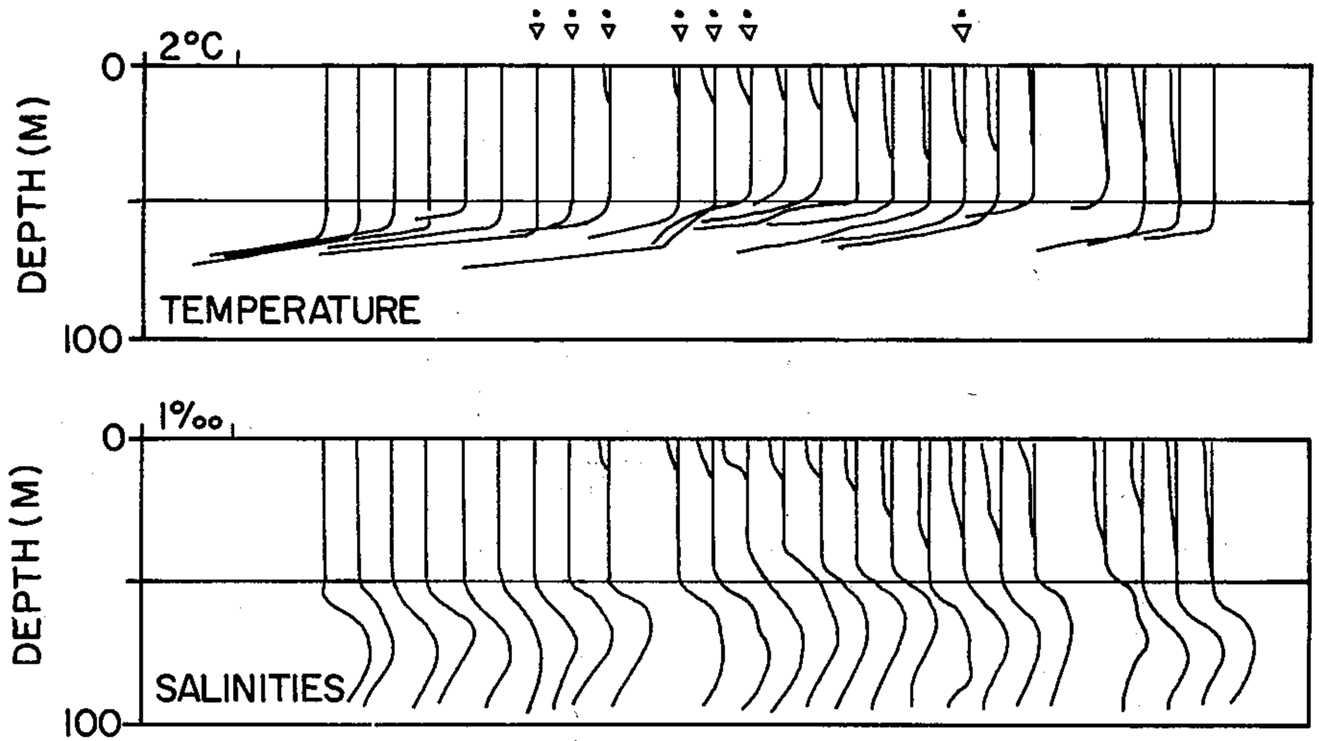

Figure 1. Temperature and salinity profiles obtained on a 2-hourly basis on July 19 and 20, 1969, at 5°N, 21°W on board the Soviet research vessel Professor Zubov. *(Ostapoff et al., 1972.)*

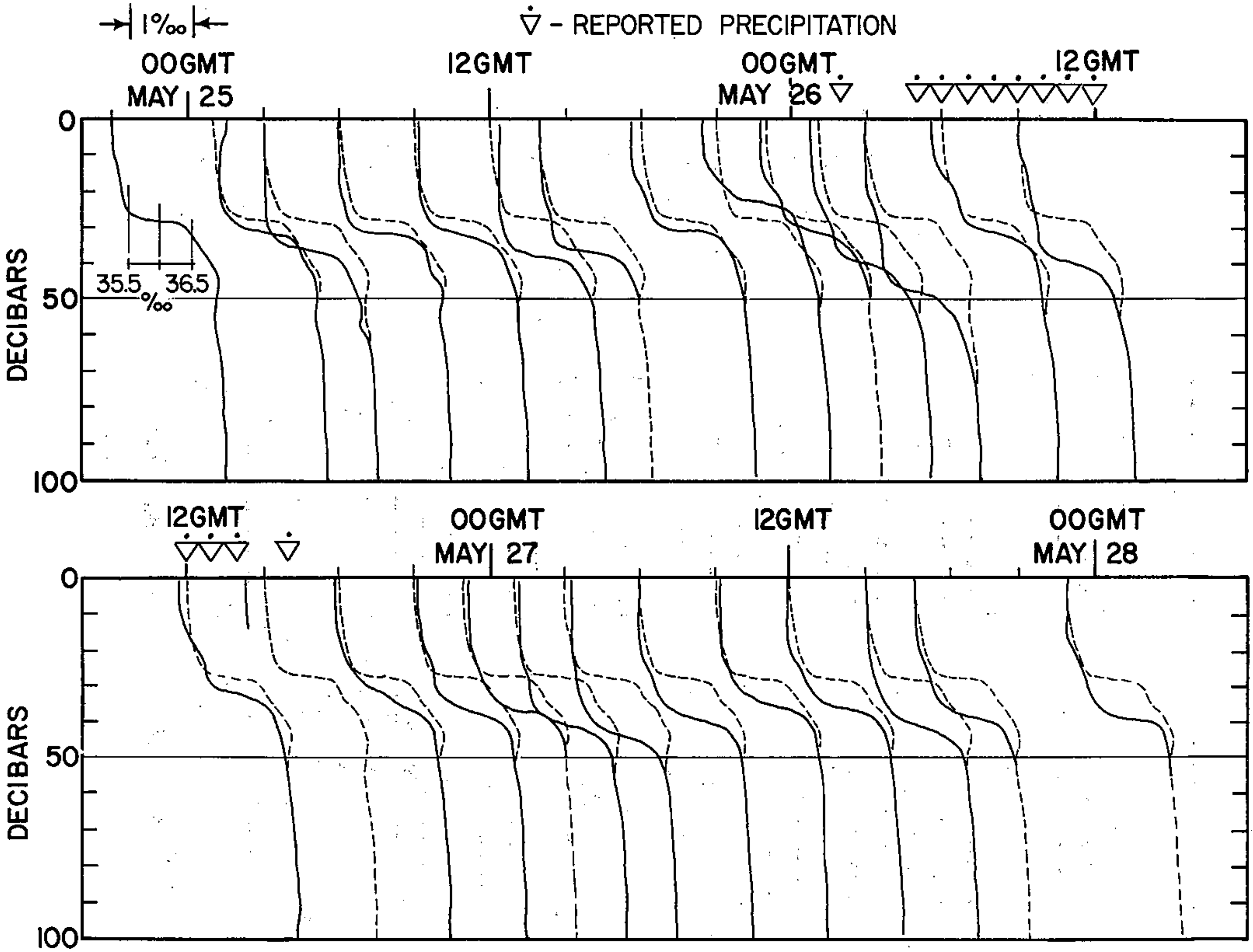

Figure 2. Salinity profiles displaced in time. Oceanographer, *1969. The salinity profile at 2100 GMT, May 24, is shown as dashed line as reference for the other profiles.*

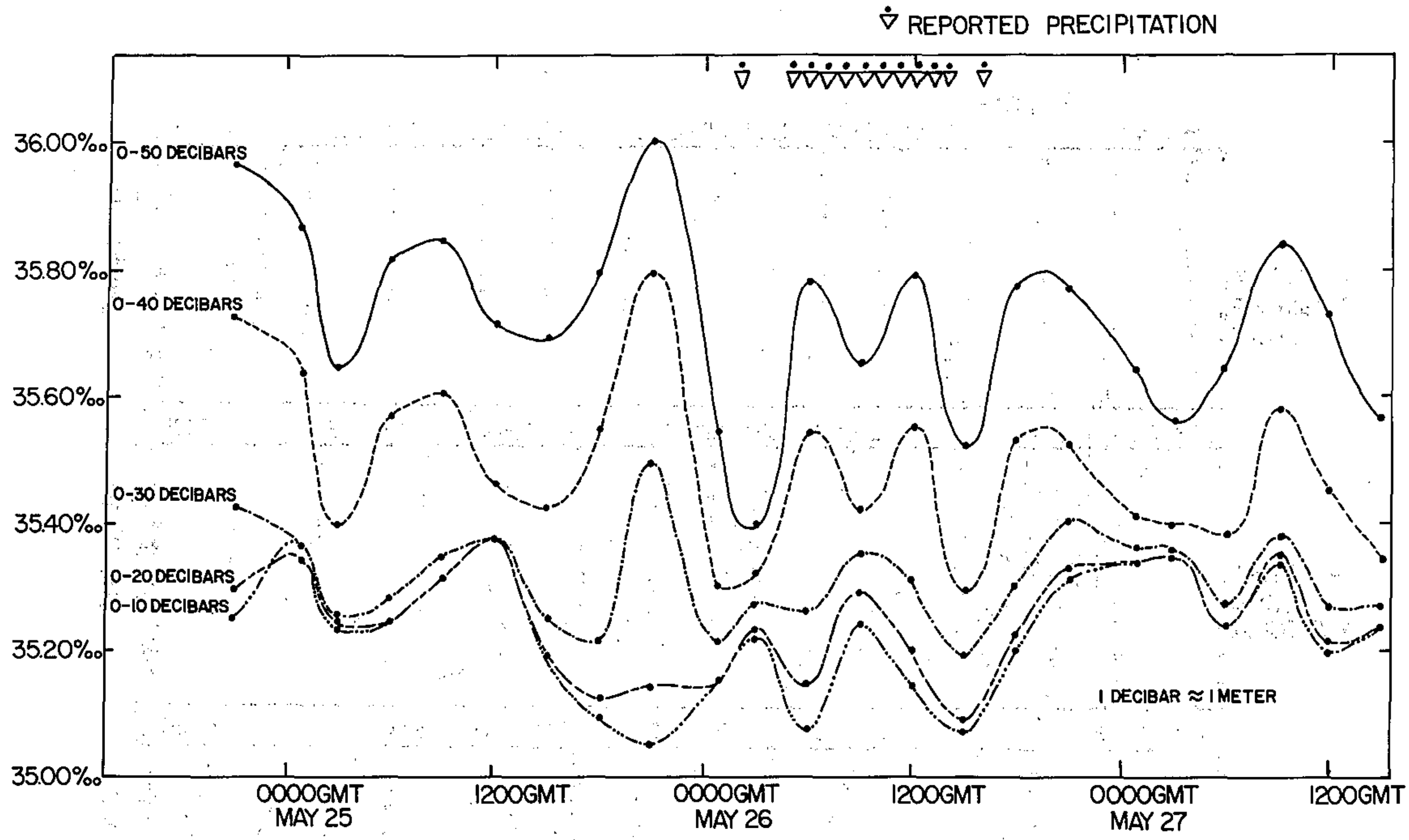

Figure 3. Depth-averaged salinities vs. time. Oceanographer, *1969.*

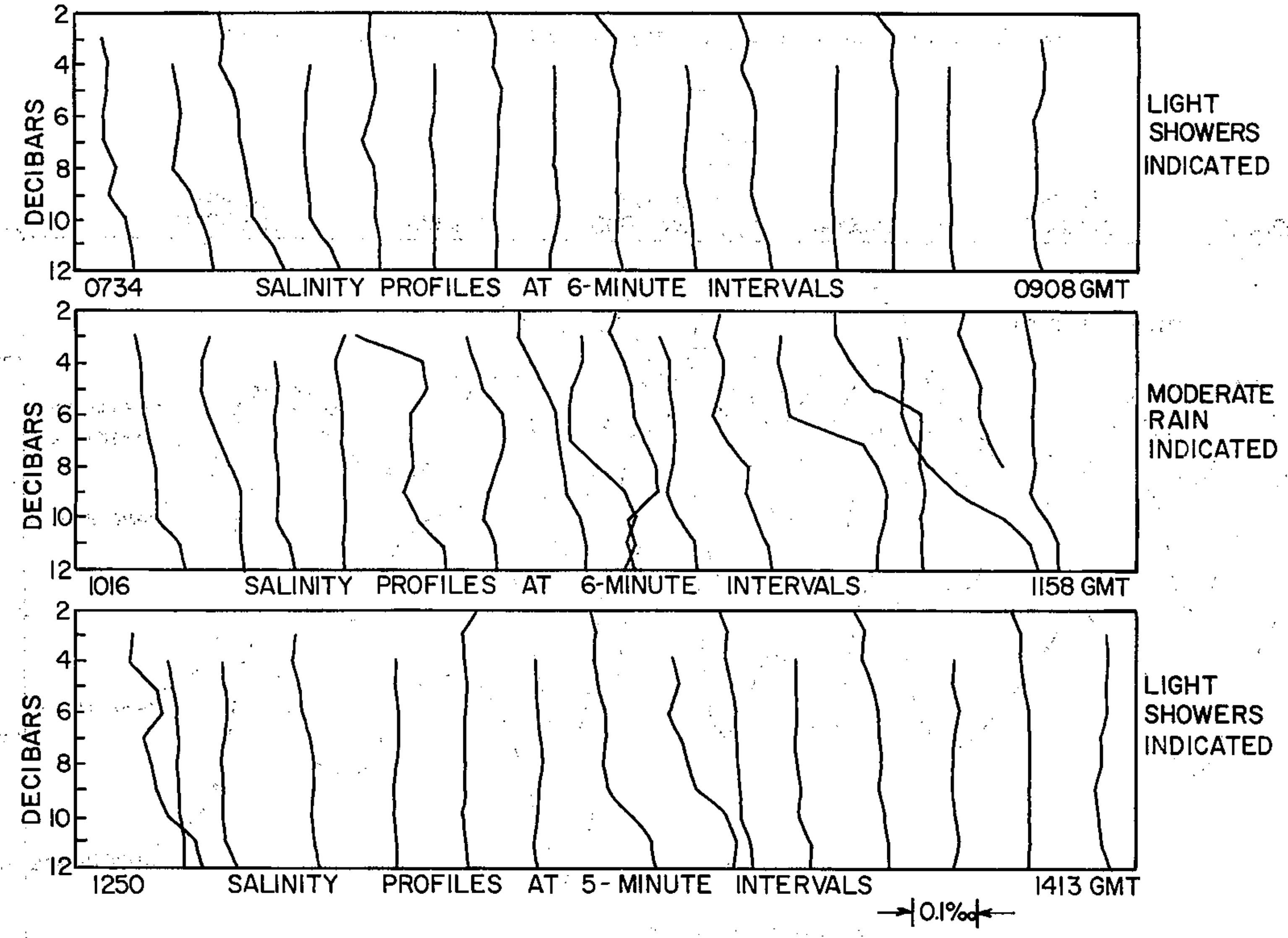

Figure 4. Salinity profiles for May 26, 1969. Oceanographer.

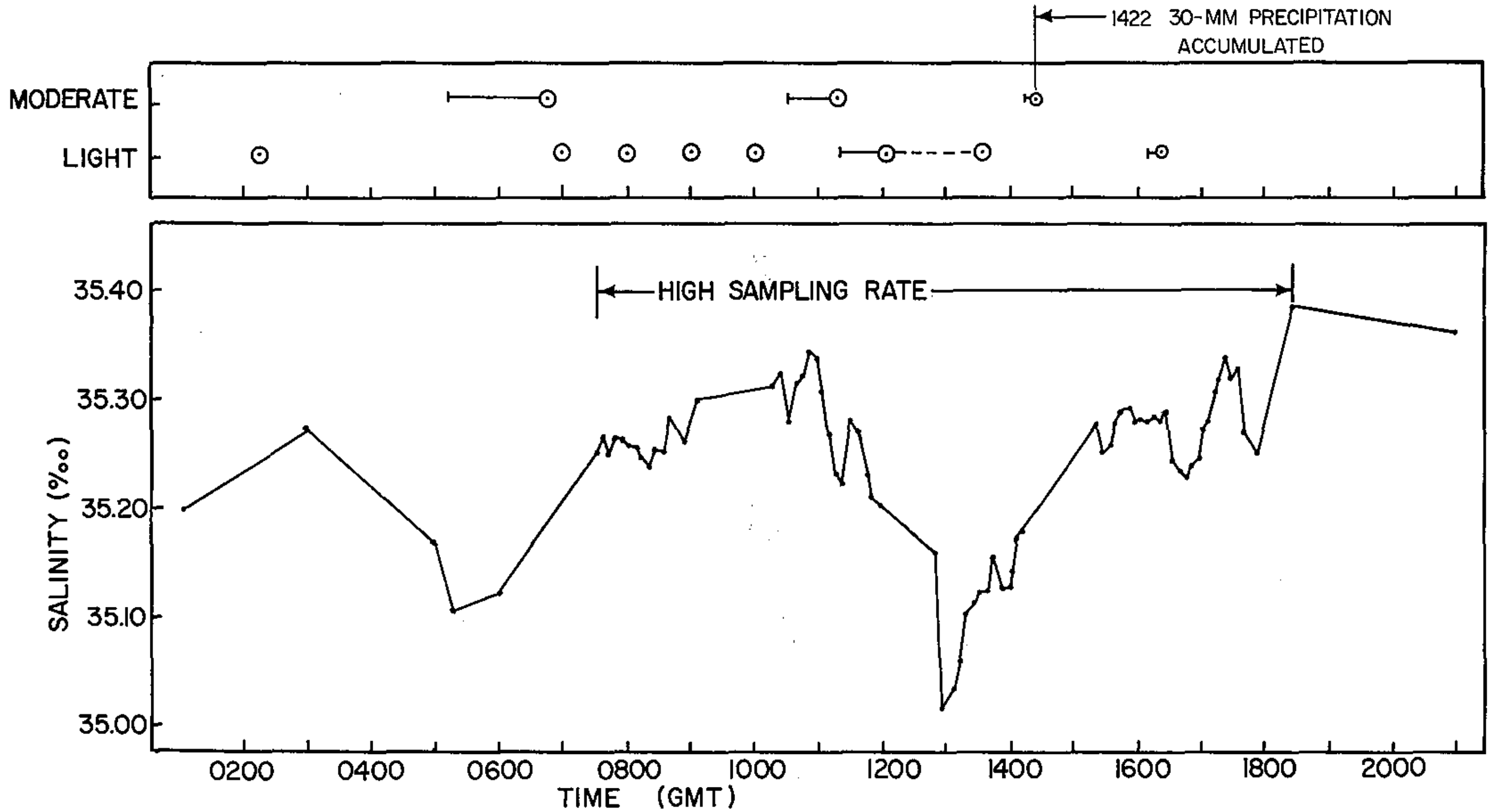

Figure 5. Top: Precipitation vs. time; ⊙ report of precipitation; ⊢⊙ intensity and duration indicated; ⊢--⊙ continuous precipitation, intensity not indicated. Bottom: Salinity averages of 0- to 10-decibar layer vs. time. Oceanographer, *May 26, 1969.*